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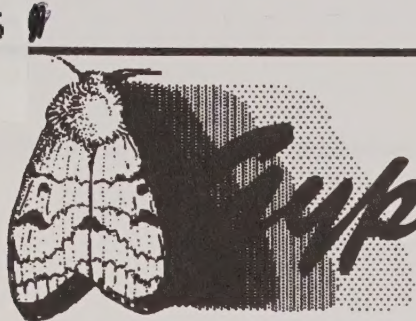
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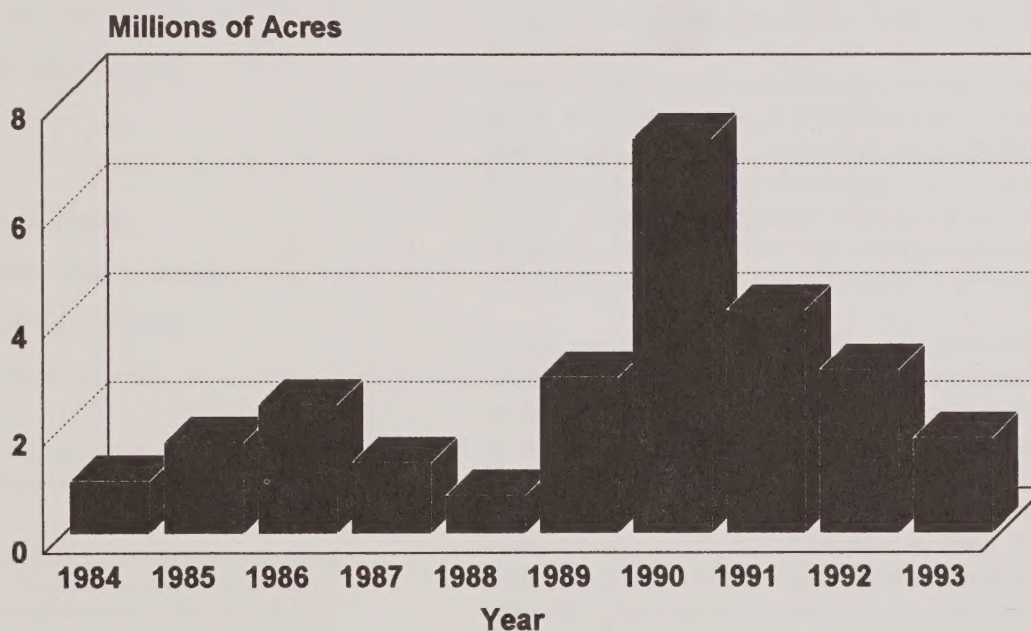
Gypsy Moth News

During 1993, the gypsy moth defoliated 1.8 million acres, a 41% decrease since 1992

Millions of Acres

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United States
Department of
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NORTHEASTERN AREA
State and Private Forestry

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From the Editor

One of the most important tenets of pest management is to consider the potential role of natural enemies in controlling the pest. The purposeful manipulation of natural enemies to reduce pest numbers is called biological control (see McManus letter). Biological control efforts have existed for many years and have recorded numerous successes. One of the more notable successes is the introduction of the predatory insect, the vedalia beetle, to control cottony cushion scale, a pest of citrus. According to an article in the Bulletin of the Entomological Society of America, in a survey of biological control literature, 602 attempts of biological control were found on a worldwide basis, with a complete success rate of 16 percent, and a partial success rate of 58 percent.

Natural enemies (imported or otherwise) have not been given much credit in developing management strategies for gypsy moth in the United States. Not much more than a paragraph or two was devoted to their use in the Environmental Impact Statement for the Appalachian Integrated Pest Management Program, and not much more than that in the orginial Environmental Impact Statement done in 1985. Part of the reason for this lack of attention is the perception that natural enemies will not regulate gypsy moth populations soon enough to avoid damage to the forest. In this issue, two articles, one by Harvey Smith and the other by Elkinton and Leibhold, describe natural enemies of gypsy moth. Both were resurrected from their previously published format in order to provide our readers with a second look at this often overlooked form of pest management.

-DBT

LETTERS TO THE EDITOR

G.B. from Massachusetts asks:

"For a brief summary of the technique used by the FS at Delaware, OH, to distinguish Asian GM from European GM, and even hybrids as recently done with specimens recovered at Wilmington, NC. How reliable is the tech.? And how does it differ from the APHIS technique?"

Dr. James M. Slavicek, USDA Forest Service, Delaware, Ohio, responds:

The technique first developed, and used initially on the samples collected from North Carolina, is a nuclear DNA randomly amplified polymorphic DNA (RAPD) assay. Nuclear DNA markers offer a DNA-based identification method that is capable of identifying Asian heritage regardless of the maternal component of the cross. This is an advantage over the mitochondrial DNA diagnostic assay developed by R. Harrison at Cornell University, and that is used at APHIS. The mitochondrial assay will only detect Asian-European hybrids that were derived from a cross of an Asian female x European male.

We have identified a RAPD primer that produces DNA fragments from Asian and European nuclear DNA that are different in size, and hence are diagnostic. This primer was used for analysis of Asian-European hybrids in collaboration with Dr. M. Keena, USDA Forest Service, Hamden, Connecticut. The expected

result of both fragments being generated in the hybrids was obtained. The same hybrid pattern was found with some of the samples collected in Sunny Point, North Carolina, indicating the presence of Asian-European hybrids.

The RAPD assay is extremely sensitive to experimental conditions such as buffer composition, DNA purity, the thickness of tubes in which the reaction is run, temperature transfer efficiency of the thermocycler etc. Consequently, if the identical conditions are not used by two different researchers, there are often quantitative and qualitative differences found in the amplification products. We have observed these differences when comparing DNA products obtained in our laboratory to those in another lab using the same DNA preps. One way to avoid these differences is through using specific PCR primers for the diagnostic fragments. To generate specific primers, the diagnostic fragments are cloned and sequenced, and the sequence information is used to design specific primers. We have cloned and sequenced the Asian and European diagnostic fragments generated to date. This information was used to design, produce, and test specific primers. Our results show that the specific primers generate diagnostic fragments for the Asian and European gypsy moth strains.

The RAPD technique developed for Asian gypsy moth identification has been

transferred to Agriculture Canada and the Animal and Plant Health Inspection Service (APHIS) for use in routine diagnostic analysis. In addition, we are in the process of transferring the specific primer PCR technique to these groups.

L.A. from Athens, OH, writes:

"I would like information about _B.t._ non-target studies in West Virginia habitats of the Virginia big-eared bat."

Dr. Robert E. Acciavatti, USDA Forest Service, Morgantown, West Virginia, responds:

I have sent several recently published documents which respond to your request of January 15, 1993, for information on the status of studies about non-target impacts of gypsy moth suppression projects on Threatened and Endangered Species. Specifically, these pertain to the Virginia big-eared bat foraging habits and effects of _Bacillus thuringiensis kurstaki_ on non-target moths, the main food source of maternal colonies of this Federally threatened and endangered mammal.

The following documents, obtained in the course of assisting the Monongahela National Forest prepare the environmental assessment for their proposed 1994 gypsy moth suppression project, should be of interest to you:

Dalton, V.M., V. Brack, and P.M. Teeter. 1986.

Food habits of the big-eared bat, *Plecotus townsendii virginianus*, in Virginia. Virginia Journal of Science, 27(4):248-254.

Sample, B.E. and R.C. Whitmore. 1993. Food habits of the endangered Virginia big-eared bat in West Virginia. Journal of Mammalogy, 74(2): 428-435.

Peacock, J.W., D.L. Wagner, and D.F. Schweiter. In press. Impacts of *B.t.* on non-target lepidoptera. Proceedings of the 1993 Annual Gypsy Moth Review, Harrisburg, PA.

T.G. from Michigan asks:

"We have been told there is no eradication of the gypsy moth, just suppression. Can you send me information on any successful eradication programs and how they differ from suppression programs?"

Donna Leonard, USDA Forest Service, Asheville, North Carolina, responds:

The difference between eradication and suppression projects can best be explained in relation to the location of a particular project. If the project area is located with the quarantine regulated area where gypsy moth is well established, such as where you are located, it is referred to as a suppression project. The general objective is to suppress targeted populations below damaging levels. The specific objectives may include protecting tree foliage, abatement of larval nuisance, or reducing tree mortality that can result from repeated, consecutive defoliations. Suppression programs are designed to reduce populations, not to eliminate them.

However, if a localized gypsy moth infestation becomes established outside of the generally infested area, the objective of the project is to eliminate or eradicate that particular isolated infestation. These infestations generally occur as a result of humans transporting articles that are infested with gypsy moth life stages, i.e., a homeowner from New York moves to Georgia, Arkansas or Utah and takes along birdhouses or outdoor furniture that are carrying gypsy moth egg masses, or infested shrubs/trees are shipped from Pennsylvania to Kansas. The next spring the eggs will hatch and if there is enough suitable host for the gypsy moth to survive, a small infestation may become established in an area that was completely free of gypsy moth. These isloated infestations are detected and delineated through the use of pheromone traps. Control measures are targeted at the entire area which is infested with the objective of eliminating the introduced population, avoiding the cost and headaches of quarantine procedures, and postponing the eventual establishment of the gypsy moth.

Since 1972 more than 230 infestations have been treated and eradicated. Oregon, Utah, North Carolina, Georgia, Tennessee, Virginia, Ohio, and Indiana have all had successful projects. For specific information on any of these projects, please contact the Department of Agriculture in the states listed.

The differences between suppression and eradication are clear, as long as the isolated infestation is well removed (>100 miles) from the generally infested area. In these cases the probability of successfully eliminating the population is high and the risk of reinfestation is relatively low. But the area considered generally infested by the gypsy moth is not static, rather it expands slowly westward and southward each year. Areas newly infested by the gypsy moth along this expanding front of populations are known as the leading edge. Gypsy moth populations that become established just ahead of the leading edge fall into a gray area, known as the transition zone, where the objectives of control projects are not as clear. The populations are not yet high enough to be causing damage, therefore, they do not warrant suppression. However, they are not well removed from the generally infested area so the risk of reinfestation is high, therefore they are not good candidates for eradication projects either.

Because traditional gypsy moth management objectives do not fit well in these areas, the transition zone has historically been a hotly debated no man's land in terms of gypsy moth management. In order to resolve this issue, the USDA Forest Service is currently cooperating with USDA Animal and Plant Health Inspection Service and four

states in a pilot project to evaluate the feasibility of slowing the spread of gypsy moth populations through intensive detection and management of low level populations in the transition zone. Hopefully the results of this pilot project will be used to formulate future management policy for gypsy moth in the transition zone.

S.R. of Bellefontaine, OH, asks:

" What organisms are being used in biological control in addition to B.t.?"

Dr. Michael McManus, USDA Forest Service, Hamden, CT, responds:

In order to properly address this question, it's important to clarify interpretation of the terminology because there are many different definitions and opinions in the literature on biological control. The regulation of pest organisms by their natural enemies is termed biological control; the natural enemies, (parasites, predators, pathogens) may be indigenous (native) or deliberately introduced from other areas of the world where the pest insect or related species exist. The use of introduced natural enemies is termed classical biological control.

The use of pathogens like *Bacillus thuringiensis* (*Bt*) to control pest insects such as the gypsy moth is referred to as microbial biological control or simply microbial control. These products must be registered with the Environmental Protection Agency (EPA) as a pesticide under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). The only microbial pesticide other than *Bt* that is registered for use against the gypsy moth is GYPCHEK, a nuclear polyhedrosis virus that is naturally-occurring in gypsy moth populations throughout its range in Europe and Asia and North America. This viral product was registered by the USDA Forest Service in 1978 but is not yet available to the public because it is not produced commercially. In recent years, the Forest Service and the Animal & Plant Health Inspection Service (APHIS) have collaborated to produce enough GYPCHEK to treat 5-10,000 acres of environmentally sensitive forested lands that are infested by the gypsy moth. The use of GYPCHEK in these situations is preferred because it only kills the gypsy moth, whereas *Bt* may affect other species of Lepidoptera as well.

Although many species of parasites have been released over the past century for classical biological control of the gypsy moth, the use of pathogens, for this purpose has received much less attention until recently. In 1989, gypsy moth larval populations in the Northeast were decimated by disease caused by an insect fungus, *Entomophaga maimaiga*. This pathogen was introduced in 1910-1911 from Japan; how-ever, it had never been recovered from gypsy moth populations in New England since that time. Scientists are still attempting to understand the mysterious reappearance of this organism and to evaluate its impact on the gypsy moth.

Researchers are also evaluating the potential of other pathogens that contribute to the natural control of gypsy moth populations in Europe and Asia but that are not present in North American gypsy moth populations. One example are the microsporidia, a class of organisms that causes chronic disease in gypsy moth larval populations in Eurasia. Like *Entomophaga maimaiga*, this pathogen is being considered for use in a classical approach to biological control and is not in-tended for application as a microbial pesticide.

U.S. SCIENTISTS EXPLORE EUROPE

By Normand Dubois and Michael Montgomery

Drs. Norm Dubois and Mike Montgomery (USDA Forest Service) visited Romania under sponsorship of the USDA's Office of International Cooperation and Development (OICD). The primary purpose of the trip was to collect microsporidia specific to the gypsy moth and to explore areas for future cooperative research and scientific exchange related to biological control. The USDA scientists were escorted by their hosts on an extensive tour of Romania's forests over a two-week period. Initially they traveled to the southeastern Carpathian Mountains and the Danube Delta, one of the more sensitive estuaries in the world and where gypsy moth population outbreaks occur on species of poplars and willow. Then, after spending a few days touring gypsy moth-infested oak stands south of Bucharest, they embarked on a seven-day trip through the Transylvania Mountain region where they visited several forest districts and research stations.

The Romanians have an aggressive program of monitoring and collecting gypsy moths and several defoliators of conifers, and have meticulous historical records accumulated over a period of many years. However, they lack the knowledge and technology to conduct efficient aerial spray programs needed to control forest defoliators and have only recently reduced their dependency on chemical pesticides for forest protection. Several species of natural enemies were abundant in gypsy moth populations; in the Danube Delta area, about 80 percent of pupae were parasitized and *Parasetigena lasius* was by far the most abundant species present.

Gypsy moth larvae were collected by Romanian technicians from six different geographical areas prior to the U.S. visit. These samples were extracted for pathogens and returned to the U.S. Ultimately, these samples were forwarded to the Illinois Natural History Survey where they were processed and analyzed. Dr. Maddox determined that microsporidia were recovered from four of the six samples along with several viral isolates and one fungal isolate that resembled *Entomophaga maimaiga*. The latter was sent to Dr. Ann Hajek, Boyce Thompson Institute, for identification and further study.

Also, Drs. Mike McManus, USDA Forest Service, and Joe Maddox, Illinois Natural History Survey, traveled to Krasnojarsk, Siberia to work with Dr. Yuri Baranchikov, with the Sukachev Institute of Wood. Under a cooperative agreement initiated in 1992, Baranchikov agreed to assist the Forest Service in recovering a gypsy moth specific microsporidian, *Nosema serbica*, which has been reported to cause significant mortality in gypsy moth populations in the former Soviet Union. In contrast to the Dubois/ Montgomery travelogue, Mike and Joe spent over two weeks in a laboratory, individually dissecting and then examining tissues from over 1,500 larvae of the Asian gypsy moth and the Nun Moth, *Lymantria monacha*, for presence of entomopathogens. Our Russian cooperators collected hundreds of larvae from infestations as far removed as Novosibirsk, 1,500 km west of Krasnojarsk, and from the Altay Mountains, 650 km southwest of Krasnojarsk and only 400 km north of the Mongolian border. Despite the Herculean effort, they were unable to isolate any microsporidians from larvae of either related species.

However, several interesting viruses were recovered from both the Asian gypsy moth and Nun Moth. Samples of the virus will be bioassayed by the Forest Service to determine their potency.

Norm Dubois is a Microbiologist and Mike Montgomery is a Supervisory Research Entomologist with the USDA Forest Service's Northeastern Center for Forest Health Research in Hamden, CT.

BIODIVERSITY AND GYPSY MOTH MANAGEMENT

By Harvey R. Smith

Integrated pest management, which includes combinations of treatments but emphasizes biological components, is an alternative to the use of pesticides alone. Predators, as biological agents, have been studied to determine their potential in management schemes. Observations suggest that predators exert a major influence in maintaining gypsy moth populations at low levels. However, biologists do not understand the actual influence of predation on those populations and have not determined the relationship of the components of biological control to overall regulation of pest populations.

The Gypsy Moth Predator Community

The literature abounds with references relating to predator-prey interactions and theory, yet much controversy remains.

The gypsy moth predator-prey system can be described by focusing on four somewhat unique attributes in predator-prey relationships. First, *the gypsy moth is an exotic species*; hence, unlike the situation in Eurasia, coevolution of predator and prey has not occurred in the United States and predator-defense mechanisms may not have similar survival value in this country. Second, *a behavioral change occurs* when the larvae are approximately half grown. Young larvae remain on or near the foliage but older larvae seek resting locations farther down the tree in bark fissures, wounds, or flaps or in the litter at the base of

the tree. Generally, they descend to resting locations at dawn and ascend at dark to feed in the canopy. This behavior may have evolved to enable the gypsy moth to evade natural enemies in Europe. Also, this behavior changes prey distribution from random to clumped, and predators may learn to locate these aggregations. Third, *the gypsy moth is an important food item for only a few of the predators* that eat it. The interactive relationships that govern what a predator eats suggest that opportunism prevails in this predator-prey system. Although opportunism is an essential attribute of all predators, here it often results in consumption of a nonpreferred food. Fourth, *defoliation may affect predator diversity and density*, and thus the dynamics of the predator-prey relationship. Although few predators of the gypsy moth show a numerical response, outbreaks can cause predators to respond numerically to a habitat altered by the prey.

The Predators

In the Northeast, many species of wildlife eat gypsy moths and other forest-defoliating insects. Forbush and Fernald (1896) listed 38 species of birds and Smith and Campbell (1978) identified 15 species of mammals that eat this insect. Smith and Lautenschlager (1978) emphasized that the predator community (including invertebrates) could maintain gypsy moth populations at low levels.

Nearly a century ago, Forbush

and Fernald recognized birds as important predators of the gypsy moth. It was not until Campbell and Sloan (1976, 1977) wrote about gypsy moth dynamics in innocuous populations that birds were mentioned again in the gypsy moth literature in this country. They determined that the year-to-year numerical stability among the sparse populations was determined largely by a combination of birds that tended to concentrate on older larvae and by small mammals, especially white-footed mice.

Hairs on the larvae evidently caused a significant reduction in predation by birds, as evidenced by the high rate of predation on other, hairless Lepidoptera. Yet nearly all species ate some gypsy moths. Few predators demonstrate a preference for gypsy moth but many include it in their diet. Overall, 24 percent of the birds ate some gypsy moth, primarily late-instar larvae. However, research findings to date suggest that avian predation is minimal and it is doubtful they play a major role in maintaining low density gypsy moth populations in North America.

Survival of Gypsy Moth Pupae

Vertebrate predators of gypsy moth pupae in the litter consisted almost entirely of white-footed mice and short-tailed, smoky, and masked shrews; birds did not appear to prey on pupae in any location. Generally, birds prey on forest insects inhabiting trees or in free flight (larvae and adults).

Preliminary indications were that invertebrates attacked a higher percentage of the stocked aggregations of pupae than vertebrates. However, vertebrates destroyed more pupae per aggregation. Subsequent studies have shown year-to-year differences in survivorship of pupae deployed in selected microhabitats were highly correlated with white-footed mouse densities. It is now generally accepted that when gypsy moths rest in the litter survival is low due to mortality caused by the ground-foraging-generalist vertebrate predators. If the gypsy moth rested in the pupal stage at random locations, the more uniformly dispersed invertebrate predators would have a greater impact. These observations could support Campbell and Sloan's (1976) contention that behavior leading to clumped dispersion may have evolved in part from selective pressures of invertebrate preda- tion. A better understanding of why the gypsy moth occurs in aggregations would enhance the ability to manage the insect. However, that the species occurs in aggregations in a variety of resting locations, each with a different inherent risk, ensures survival as those insects in lower risk resting locations have higher survival rates.

The Importance of Forest Diversity

Forests vary in their susceptibility to defoliation by the gypsy moth. Susceptible forests characteristically are on dry sites where trees (mainly oaks) are scrubby with numerous structural features such as bark flaps, wounds, and deep bark fissures.

These sites are open, and have little or no leaf litter.

Conversely, resistant stands typically grow on well-drained, deep loam soils where moisture is not limited; trees maintain a good growth rate and are relatively free of structural features. Resistant stands have much greater vegetation diversity and a deep layer of litter.

Species diversity is much greater in resistant than susceptible stands for both birds and mammals.

Vegetation diversity, height of canopy, canopy cover, and overall density of vegetation decreases as one ascends to a ridge. Thus, niche space available for birds is diminished. Subsequently, the number of species and individuals is reduced on the ridge. Birds most notably absent from the ridge are those species belonging to the foliage-insect feeding group and those in the foliage-nesting group.

The number of coexisting species of small mammals is largely a function of the size and diversity of microhabitat con-contained within a vegetative community and the size of the site. The higher diversity observed on lower slopes is consistent with the results of earlier studies. In my studies on Bryant Mountain in Vermont, I found that habitat diversity declines as one ascends the mountain. Four species were found exclusively in the lower slope: smoky shrew, hairy-tailed mole, woodland jumping mouse, and red-backed vole. Abundance of shrews is positively associated with the mesic conditions found

in the lower slope habitat (e.g. decaying logs, woody debris).

FOREST STEWARDHIP

Over the past decade, biologists have described the gypsy moth predator complex and many interactive relationships that make predators a major suppressive force in population dynamics of the insect. Although additional information is needed before gypsy moth predator-prey theory can be integrated into a control program that is both biologically and economically feasible, numerous management implications can be defined. *Forest stewardship practices should be oriented toward providing optimum diversity* (floral and faunal). This should not be confused with the controversy regarding the concept that increasing diversity of species stabilizes the forest community. Valentine and Houston (1979) were able to discriminate between forests susceptible or resistant to defoliation by gypsy moth by using variables that reflected the abundance of structural features. The implications of my studies suggest that susceptibility is enhanced because of reduced predator diversity and density in those areas high in structural features.

Reduced predator efficiency on gypsy moths can occur naturally through increasing availability of more preferred foods. I suggest that predation efficiency on this species can be enhanced by manipulating alternative prey populations. Enhancing predator potential has merit if prey behavior, predator food preference, and predator foraging strategy are understood. For example, re-

ducing the number of low-risk resting locations (removing bark flaps) would cause more larvae to rest in the litter, where mortality has been shown to be greatest.

Biologists must provide food and cover for wildlife if maximum use of predators in management of forest pest insects is to be realized. Cuckoos, for example, are the most voracious bird predators on gypsy moth caterpillars, and their numbers increase in areas with patchy thickets in the understory. Shrews, known for their voracious appetites and ability to destroy many gypsy moth larvae and pupae, require an abundance of decaying logs and woody debris to enhance their populations.

SUMMARY

Predators of the gypsy moth are opportunistic feeders; selection is largely a function of the availability of other foods. The gypsy moth predator-prey system is complex; many wildlife species eat gypsy moths. Avian, mammalian, and invertebrate predators of gypsy moths are the most common and important. Gizzard analysis of 557 birds of 17 species collected in Massachusetts and New York revealed that 24 percent contained gypsy moth remains, primarily late-instar larvae. In a Connecticut study, predators destroyed 43 percent of the pupae; mortality was greatest in the litter layer (65 percent). Pupal mortality on the bole and under bark flaps was 32 and 29 percent, respectively. Shrews and mice accounted for nearly all of the vertebrate predation; invertebrates, primarily ants and beetles, accounted for

the remaining mortality. Avian and mammalian diversity and abundance were lower on sites susceptible to defoliation by moths, suggesting that susceptibility is correlated with predator diversity and density. The impact of predators on population dynamics of the gypsy moth can be enhanced by either management of predators through increased food and cover, management of the forest through reduction in availability of alternative prey, or reducing the number of resting locations where moth survival is high. Further research on how alternative foods affect predator feeding behavior and the interactions of predators with other natural enemies of the moth is needed. Predation is a major source of mortality of low-density gypsy moth populations. Effective predation is dependent on ecosystem interrelationships. Our ability to understand predator-ecosystem interrelationships will largely determine the effectiveness and ecological compatibility of future forest pest management scenarios.

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THE DYNAMICS OF GYPSY MOTH PREDATORS, PARASITES, AND PATHOGENS

By J.S. Elkinton and A.M. Liebhold

The first detailed life-table study of gypsy moth populations in North American was that of Bess and others in 1947, who constructed survivorship curves for a population in Freetown, Massachusetts. They found that densities declined dramatically during the fifth and sixth instar. Campbell (1967) concluded from analyses of data collected in Connecticut and New York that *variation in late larval survival was the largest source of yearly variation in population density, mortality during late-larval and pupal stages was density dependent and thus might serve to regulate population growth.*

THE WHITE-FOOTED MOUSE

The first to suggest that predation by small mammals was important to gypsy moth population dynamics in North America was Bess and others in 1947. They showed that larval survival was significantly higher on trees inside fences that excluded small mammals. Bess' hypotheses concerning the impact of small mammal predation on low-density gypsy moth populations were supported by subsequent studies. Campbell and Sloan, in 1977, found that predators, **especially the white-footed mouse**, *Peromyscus leucopus*, were the major source of late-larval and pupal mortality. Pupae in the litter were less likely to survive to the adult stage than pupae in protected locations on tree stems,

even though the majority of individuals pupated in the litter.

In low-density poulations, overall larval mortality and predation rates on pupae were positively correlated with gypsy moth population density. *These findings support the hypothesis that predation by small mammals is responsible for the regulation of low-density gypsy moth populations.* At higher gypsy moth densities, predation by small mammals was much lower, presumably becuse the numerical response of most vertebrate predators is highly constrained. At low gypsy moth densities, increases in predation presumably arise from changes in foraging behavior (learning) of the predators resulting in an increased rate of predation rather than increases in predator density. This, however, has not been demonstrated experimentally (Elkinton et. al, 1989). We are aware of no evidence that gypsy moth populations significantly affect the reproductive success of the white-footed mouse or any other small mammal. Most of the small mammals and birds that feed on gypsy moth are generalists for which gypsy moth is a minor component of their diet.

In our studies with gypsy moth populations on Cape Cod and in western Massachusetts, substantial mortality in **high-density** populations was caused by nuclear polyhedrosis virus

(NPV), but in low-density populations, parasitism, particularly from *Parasetigena silvestris* (a parasitic fly), has been a major factor. However, viral disease and parasitism have usually accounted for less than 50 percent of the total mortality during the late larval stage. Losses during this stage appear to be caused mainly by predation. At these same sites we estimated small mammal densities and measured the predation rate on pupae that we deployed in the litter. The white-footed mouse was by far the most abundant small mammal predator captured in our traps, and the rate of pupal predation was highly correlated with its density. In 1986, we observed a dramatic decline in *P. leucopus* density on plots in western Massachusetts and a concomitant increase in gypsy moth density. Very similar trends have been noted on Bryant Mountain in Vermont. *These findings are consistent with Campbell and Sloan's hypothesis (1977) that variation in predation on pupae and the late-larval stage is the key to whether or not populations remain stable at low density.* The occurrence of such simultaneous trends at widely spaced sites suggests that regional changes in small mammal density may account for the region-wide onset of outbreak phase populations of gypsy moth.

Recent studies have identified other factors that affect predation by small mammals. Smith in

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1989 showed that an abundance of alternate foods, such as blueberries, can markedly reduce small mammal predation on gypsy moths.

PARASITES

Gypsy moth parasitoids have been widely studied, but most researchers believe that they do not play a major role in the population dynamics of this defoliator in North America. Beginning in 1905, extensive efforts were made to introduce gypsy moth parasitoids from Europe and Asia into North America. Of ca. 40 species that were introduced, ten have become established.

The principal egg parasitoids in North America are *Ooencyrtus kuvanae* (a small wasp) and *Anastatus disparis*. The latter parasitoid is only occasionally a significant source of mortality to gypsy moth on this continent. *O. kuvanae* typically attacks from 10 to 40 percent of eggs per mass. Parasitism by *O. kuvanae* is greater on smaller egg masses, which characterize high-density or collapsing gypsy moth populations. This occurs because *O. kuvanae* attacks only the eggs on the surface of the mass and smaller masses have a higher proportion of eggs near the surface.

Parasetigena silvestris is a tachinid (fly) that oviposits large eggs on the integument of larvae. It is most active during daylight hours, and it concentrates attacks on larvae on the stems of trees, particularly when the larvae are moving between the canopy and daytime resting locations at dawn or in the evening. *P. silvestris*

often causes more mortality than any other parasitoid, and peak parasitism typically occurs after gypsy moth populations decline from high density. In European populations, *P. silvestris* sometimes exceeds 95 percent (Montgomery and Wallner, 1988). It appears to exhibit a classic delayed density-dependence which may account for the regular cycles of gypsy moth evident in some European populations as shown by Turchin (1990).

The tachinid, *Compsilura con-cinnata*, is a parasitoid of gypsy moth larvae with a wide host range. Because it depends on alternate hosts, *C. concinnata* would not be expected to exhibit strong numerical responses between generations of gypsy moths. On the other hand, unlike parasitoids that specialize on gypsy moth, it can remain abundant when gypsy moth populations are very sparse. Consequently, *C. concinnata* often causes higher mortality than any other parasitoid, when gypsy moth populations are at low density.

We have conducted a series of experiments to explore the response of parasitoids to artificially elevated densities of gypsy moth larvae on plots (Gould et. al, 1990) . We found that *C. concinnata* and, to a lesser extent, *P. silvestris* caused mortality that was spatially density dependent; this mortality resulted in the collapse of such artificial populations. Similar results have been obtained in Vermont and Pennsylvania. **We suspect that these parasitoids may play an important role in suppressing incipient outbreak**

populations but that such population declines may go unnoticed. Assuming that this density-dependent response is a result of aggregation of these parasitoids into stands with high host density, then the response may not occur if gypsy moth populations rise simultaneously over large areas.

PATHOGENS

High-density populations of the gypsy moth eventually collapse owing primarily to the action of pathogens, especially the gypsy moth nuclear polyhedrosis virus (NPV). Mortality from NPV usually peaks during late-larval instars. Early investigators believed that gypsy moth NPV existed in a latent form within the host insect and that epizootics were triggered by environmental stresses. Campbell in 1967 indicated that the collapse of high-density populations often was associated with years of heavy rainfall in June. Doane in 1970, however, proposed an alternate theory based on density-dependent transmission of virus particles on the foliage consumed by larvae. He demonstrated that gypsy moth neonates acquired lethal doses of virus by ingesting egg chorions following hatch. Doane suggested that NPV from the cadavers of these neonates provides the inoculum that caused late larval mortality. Studies by Woods and Elkinton (1987) support this conclusion.

There is an interaction between foliage chemistry and susceptibility of larvae to NPV. Gypsy moth larvae ingesting NPV on leaves of aspen have higher rates of mortality from the

virus than do larvae fed on red oak. Furthermore, larvae fed leaves from trees with high tannin content had reduced susceptibility to NPV. Tannins apparently bind with viral particles in the gut, inhibiting passage through the peritrophic membrane. Foliage chemistry also affects midgut pH, which, in turn, affects dissolution rates of the protein matrix in which the virus particles are imbedded.

Several other pathogens play important roles in gypsy moth population dynamics in North America. In 1989 an epizootic of *Entomophaga* decimated gypsy moth populations throughout New England (Hajek et. al, 1990). In subsequent years. *E. maimaiga* epizootics have been observed in most of the range of gypsy moth in North America. The *E. maimaiga* strains causing this mortality appear to have originated from an introduction during the early 1900's. It is not clear why this pathogen did not cause substantial effects in earlier years. It is still too early to tell how *E. maimaiga* will affect the long term dynamics of gypsy moth in North America, but it is possible that it may cause a reduction in the frequency and duration of damaging outbreaks.

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NORTH CAROLINA UPDATE

By Michael D. South

On July 4, 1993, a container vessel, the USS ADVANTAGE, arriving from Nordenham, Germany, docked at the military ocean terminal, Sunny Point, North Carolina. Through the combined efforts of North Carolina Department of Agriculture and APHIS, an intensive trapping grid was put in place, and it was determined from specimens col- lected that the ship was infested with a hy-

brid strain of the gypsy moth with DNA heritage of both the Asian and European gypsy moths. The ammunition containers that were infested had been stored at an ammo dump in Lorsch, Germany, and the pupa had attached themselves at that site.

On August 24, 1993, the North Carolina Commissioner of Agriculture appointed a management

team and a science advisory panel to deal with the introduction of gypsy moth. The science advisory panel developed treatment/ monitoring proposals based on pheromone trap data, prevailing winds, genetic information, and other relevant data. The areas of probable infestation were divided into five priority zones (Figure 1).

Gypsy Moth Eradication Project in North Carolina
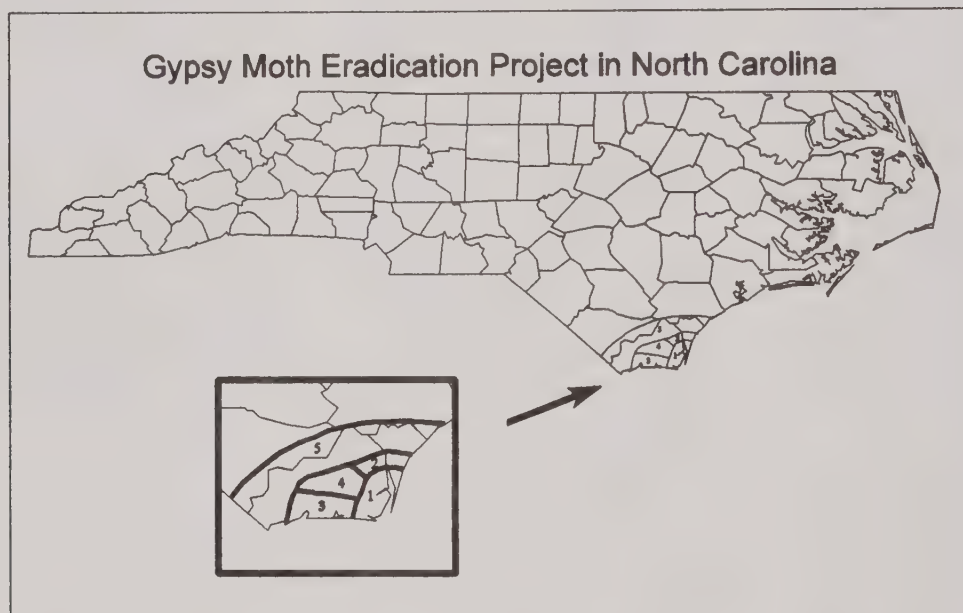
Priority Zone 1 (40,000 acres):
This is the zone considered to have the highest risk of possible infestation. Treatment recommendations are 2 or more applications of *B.t.* as needed followed by a trapping array of 25 traps per square mile. The traps would be serviced twice during male moth flight and all positive catches would warrant an immediate response at 9 traps per acre.

Priority Zone 2 (68,000 acres):
It is proposed that this zone receive the same treatments/trapping as Zone 1.

Priority Zone 3 (22,000 acres):
It is proposed that this zone receive the same treatments/ trapping as Zones 1 and 2.

Priority Zone 4 (58,000 acres):
Due to the low number of male moth catches (2) and the large number of negative trap catches in this zone, it was proposed that it receive no treatments and be trapped at the same density as Zones 1-3. The main difference would be during peak moth flight, the traps would be serviced on 3-day intervals and positive trap catches would trigger intensive (9 per acre) trap deployment.

Priority Zone 5 (858,240 acres):
Zone 5 was established to include the probable extent of maximum dispersion. It will receive no treatments but be trapped at the same level as Zone 4 but would be checked only twice during peak moth flight. Any find during peak moth flight would trigger an intensive trapping (9 per acre) trap deployment.

Mike South is the Officer in Charge for the USDA-APHIS, Plant Protection and Quarantine Office in Goldsboro, NC.

PROPOSED 1994 ERADICATION PROJECT FOR WISCONSIN

Treatment recommendations have been finalized in Wisconsin for 1994. The estimated acreage proposed for spray will be 54,375 acres proposed for 2-3 applications of the biological insecticide *Bacillus thuringiensis* variety *kurstaki* (Btk). This involves 23 different sites in the following counties: Marinette, Oconto, Brown, Manitowoc, Sheboygan, Winnebago, Jefferson, Dane, and Rock Counties. Mass trapping is proposed on 198 acres at 7 sites in Milwaukee, Waukesha, Dane, Fond du Lac, and Manitowoc Counties. No National Forest lands in Wisconsin areproposed for treatment in 1994.

These proposed treatment areas will be further analyzed through an Environmental Assessment prepared through cooperation between State and Private Forestry and the Wisconsin Department of Trade and Consumer Protection. USDA-APHIS is also a cooperator in this project along with the Forest Service. The Forest Service, through S&PF, and APHIS have a memorandum of understanding on which agency will provide cost-share dollars for gypsy moth activities in a state.

In the 1994 proposed spray project for Wisconsin, the USDA Forest Service will cost-share on approximately 53,120 acres and APHIS on approximately 1,255 acres.

One site in Marinette County, called Thunder Mountain, is within 2 miles of the Nicolet National Forest boundary. The proposed treatment block in that area is 1,000 acres.

THE INCIDENT COMMAND SYSTEM (ICS)
By Bob Adams

The Incident Command System (ICS) is the operational component of the National Interagency Incident Management System (NIIMS). NIIMS was developed by a group of local, State and Federal agencies with wildland fire protection responsibilities to improve the ability of fire protection forces to respond to any kind of an emergency. Although NIIMS was developed by wildland fire protection agencies, the management concepts can be used to respond to public emergencies of any type, as well as non-emergency situations where clearcut organization is needed. Examples of non-emergency situations include such things as conference planning and management, and gypsy moth aerial spray programs.

NIIMS consists of five major subsystems which collectively provide a total systems approach to incident management:

Incident Command System (ICS) is the on-scene management structure.

Training is a standardized subsystem that supports effective operations.

Qualifications and Certification is a subsystem that provides standards to be met by personnel who are to be assigned to incidents at Regional orNational levels. Local standards may also be developed to meet local needs.

Publication Management System (PMS) is a subsystem used to develop, publish and distribute NIIMS materials, including standardized training materials.

Supporting Technologies include such items as new mapping systems, infrared systems, and communications.

The purpose of this article is to examine the use of ICS in Forest Health Protection projects. To accomplish this, we will review the organizational concept of ICS and then apply it to a gypsy moth aerial spray project:

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The ICS organization consists of five components that need to be accounted for (actually these are identifiable any time we organize to accomplish a task!). Note that from one organization to another, or one incident to another, the ICS organization will not always look the same!

1. Command This component is the "boss" or "project leader" or "Incident Commander (IC)." Command Staff elements could include a Safety Officer, Public Affairs Officer or Media Liaison, Liaison with other agencies, or other advisors needed.

2. The Operations Section is the component that carries out the activities needed to complete the project. It may consist of ground and air branches, as well as tactical resources.

3. The Planning Section develops the Incident Action Plan (IAP) that is based on the purpose of the project, resources available to accomplish it, and unique requirements such as the weather "spray window" for aerial application.

4. The Logistics Section is responsible for supplying and caring for the goods, services, and personnel to accomplish the project. It may consist of a service branch that would provide communications and food service, and a support branch that pro- vides facilities and supplies.

5. The Finance Section is responsible for timekeeping, procurement, cost accounting, contract management and similar financial items.

PLEASE NOTE: A common misunderstanding of the use of ICS is that all of these primary positions need to be filled, as well as the supporting Unit Leaders, Task Force Leaders, and others. This is **NOT** the case! Only those positions needed to accomplish the task are filled! For example: the Logistics Section Chief may also serve as the Communications Unit Leader, or the Incident Commander may also serve as the Liaison Officer.

Keeping in mind the basic ICS components of Command, Operations, Planning, Logistics and Finance, a "do it yourself ICS development plan" to accomplish a project might look like this:

1. Get all of the "players" together and do a labeling exercise where all of the things and personnel requirements for the project are identified.

2. Sort this information into similar entities. These groups can then be labeled as "Operations", "Plans", "Logistics", "Finance" and "Command".

3. Discuss with the group of players their qualifications and experiences in the type of project work that is being planned. Note that some personnel will be qualified and experienced in wildfire management and they will be cataloged in the "Red Card" system. To accomplish your project, you need to inven- tory the skills and experiences of the personnel assigned. Then you can seek additional, needed per- sonnel to fill out your organization.

4. Develop a table of organization and place the names of your personnel in appropriate

functions, i.e., Incident Commander, Operations Section Chief, Safety Officer, Heliport Manager, etc. This "wiring diagram" should identify each position by title and show the interrelationships of each.

5. Implement your ICS Team on the project. Provide status checks during the project and a quality post project review that covers your organization as well as project completion and cost analysis.

There are a number of good references to assist the development of an ICS Team to conduct project work: The ICS Operational System Description, The Fireline Handbook and the ICS Field Operations Guide are easily available through Forest Service and other natural resource management agency offices.

There are several formal training courses available, too. The primary course is Basic ICS. These sources provide job descriptions for all positions in the ICS structure. The job descriptions can be utilized and tailored for all ICS applications.

Bob Adams is a Forester with the Forest Health Protection Staff, USDA Forest Service, Radnor, PA.

NORTHERN EXPOSURE

SOURCEBOOK FOR MANAGEMENT OF THE GYPSY MOTH

Forestry Canada (V. Nealis and S. Erb) has produced a very nice, informative booklet that summarizes concepts and information relevant to local gypsy moth management programs.

Excellent graphics and text describe gypsy moth biology and ecology (including some very nice full color photographs). Mangement activities such as control, public information programs, and integrated pest management are also covered.

The 48-page sourcebook was designed for Ontario--but anyone involved in gypsy moth management will find it useful. Copies can be obtained by writing to:

Vincent G. Nealis
Great Lakes Forestry Centre
1219 Queen Street, East
P.O. Box 490
Sault Ste. Marie, Ontario
P6A 5M7 Canada

VIRUS VIDEO

The American Cyanamid Company and the Forest Pest Management Institute of the Department of Natural Resources Canada have produced a 13-minute video on the gypsy moth virus. The video and a brochure that accompanies it are available from:

Information Services
Forest Pest Management
    Institute
1219 Queen Street, East
P.O. Box 490
Sault Ste. Marie, Ontario
P6A 5M7   Canada

GYPSY MOTH DEFOLIATION IN THE USA - 1993

STATE	TOTAL ACRES DEFOLIATED
Connecticut	0
Delaware	26,687
Maine	50,694
Maryland	68,850
Massachusetts	88,684
Michigan	399,306
New Hampshire	10,075
New Jersey	27,710
New York	2,000
North Carolina	0
Ohio	610
Pennsylvania	331,581
Rhode Island	0
Utah	0
Vermont	0
Virginia	589,100
West Virginia	202,490
Total USA	1,797,787

GYPSY MOTH DEFOLIATION IN CANADA - 1993

Region	Total Acres Defoliated
Maritimes	0
Quebec	0
Ontario	24,176

Source: Data obtained from the GMDigest, Forest Health Protection, Morgantown, WV (2/15/94).